

**HEAD SHOCK RESISTANCE AND HEAD LOAD/UNLOAD
PROTECTION FOR REDUCING DISK ERRORS AND DEFECTS,
AND ENHANCING DATA INTEGRITY OF DISK DRIVES**

BACKGROUND OF THE INVENTION

1. Technical Field:

The present invention relates in general to an improved disk drive, and in particular to an improved apparatus and method for protecting disks in a disk drive from head shock-induced errors and damage.

2. Description of the Related Art:

Generally, a data access and storage system consists of one or more storage devices that store data on magnetic or optical storage media. For example, a magnetic storage device is known as a direct access storage device (DASD) or a hard disk drive (HDD) and includes one or more disks and a disk controller to manage local operations concerning the disks. Disks are rigid platters that are usually made of aluminum alloy or a mixture of glass and ceramic, and are covered with a magnetic coating. Typically, two or three disks are stacked vertically on a common spindle that is turned by a disk drive motor at several thousand revolutions per minute (rpm).

The only other moving part within a typical HDD is the actuator assembly. Within most HDDs, the magnetic read/write head is mounted on a slider. A slider generally serves to mechanically support the head and any electrical connections between the head and the rest of the disk drive system. The slider is aerodynamically shaped to glide over moving air in order to maintain a uniform distance from the surface of the rotating disk, thereby preventing the head from undesirably contacting the disk.

Typically, a slider is formed with an aerodynamic pattern of protrusions (air bearing design) on its air bearing surface (ABS) that enables the slider to fly at a constant height close to the disk during operation of the disk drive. A slider is associated with each side of each platter and flies just over the platter's surface. Each slider is mounted on a suspension to form a head gimbal assembly (HGA). The HGA is then attached to a semi-rigid actuator arm that supports the entire head flying unit. Several semi-rigid arms may be combined to form a single armature unit.

Each read/write head scans the surface of a disk during a "read" or "write" operation. The head and arm assembly is moved utilizing an actuator that is often a voice coil motor (VCM). The stator of a VCM is mounted to a base plate or casting on which the spindle is also mounted. The base casting is in turn mounted to a frame via a compliant suspension. When current is fed to the motor, the VCM develops force or torque that is substantially proportional to the applied current. The arm acceleration is therefore substantially proportional to the magnitude of the current. As the read/write head approaches a desired track, a reverse polarity signal is applied to the actuator, causing the signal to act as a brake, and ideally causing the read/write head to stop directly over the desired track.

Disk drive sliders are susceptible to micro-cracks, fissures, corner-rounding, and edge-rounding effects due to the shock that results from the sliders landing on the disk from a load/unload platform. Disk damage may ensue when sliders come into direct contact with the disk surface when the slider air bearing has not been well established. This is typically seen in shock events, e.g., when loading heads onto the disk surface from a load/unload platform. For this reason, a disk area near the load platform is usually not qualified to be a data zone since the shock caused by errors in loading the sliders onto the disk causes dings and scratches in the media.

In addition, non-operational and operational z-axis shock can also create head

and disk damage due to the high deceleration forces that occur when the disk drive is bumped or dropped during operation. This problem is especially true of mobile drives. To protect the sliders and disks from these shock events, an improved technique is needed that will aid in shock protection, and minimize wear and scarring events that happen when the slider contacts the disk at high speeds.

SUMMARY OF THE INVENTION

One embodiment of a slider in a disk drive has a layer of shock protection by means of an overcoat layer of either metal or polymer only on the areas of the slider that are prone to contact the disk when the head is loaded off the platform, or when the head is shocked while in operation over the data zone of the disk. The material used to form the layer absorbs shock and reduces wear, and is bonded or sputtered to the slider in a region other than the air bearing surface. This region is typically the reactive-ion etched surface area and is slightly recessed below the air bearing surface of the slider. In an alternate version of the invention, the slider is protected by covering only the edges of the slider with a suitable material.

The foregoing and other objects and advantages of the present invention will be apparent to those skilled in the art, in view of the following detailed description of the preferred embodiment of the present invention, taken in conjunction with the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the features, advantages and objects of the invention, as well as others which will become apparent, are attained and can be understood in more detail, more particular description of the invention briefly summarized above may be had by reference to the embodiment thereof which is illustrated in the appended drawings, which drawings form a part of this specification. It is to be noted, however, that the drawings illustrate only a preferred embodiment of the invention and is therefore not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

Figure 1 is a plan view of a disk drive constructed in accordance with the present invention.

Figure 2 is a plan view of a first embodiment of a head for the disk drive of **Figure 1** and is constructed in accordance with the invention.

Figure 3 is a plan view of a second embodiment of a head for the disk drive of **Figure 1** and is constructed in accordance with the invention.

Figure 4 is a plan view of a third embodiment of a head for the disk drive of **Figure 1** and is constructed in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to **Figure 1**, a schematic drawing of one embodiment of an information storage system comprising a magnetic hard disk file or drive **11** for a computer system is shown. Drive **11** has an outer housing or base **13** containing a plurality of stacked, parallel magnetic disks **15** (one shown) which are closely spaced apart. Disks **15** are rotated by a spindle motor located therebelow about a central drive hub **17**. An actuator **21** comprises a plurality of stacked, parallel actuator arms **25** (one shown) in the form of a comb that is pivotally mounted to base **13** about a pivot assembly **23**. A controller **19** is also mounted to base **13** for selectively moving the comb of arms **25** relative to disks **15**.

In the embodiment shown, each arm **25** has extending from it a pair of parallel, cantilevered load beams or suspensions **27** with a longitudinal axis **28**. A head gimbal assembly **29** having at least one magnetic read/write head mounted on a slider is secured to a flexure that is flexibly mounted to each suspension **27**. The read/write heads magnetically read data from and/or magnetically write data to disks **15**. Suspensions **27** and their flexures have a spring-like quality which biases or maintains them in substantially parallel relationship relative to one another. A motor voice coil **31** housed within a conventional voice coil motor magnet assembly (not shown) is also mounted to arms **25** opposite head gimbal assemblies **29**. Movement of an actuator driver **33** (indicated by arrow **35**) moves head gimbal assemblies **29** radially across tracks on the disks **15** until the heads on assemblies **29** settle on the target tracks. The head gimbal assemblies **29** operate in a conventional manner and typically move in unison with one another. Each suspension **27** also has a load/unload tab **37** for engaging a ramp **39** located adjacent to the radial outer edge of disk **15** during loading and unloading sequences.

Referring now to **Figure 2**, a first embodiment of a slider **41** having a generally rectangular base with a top air bearing side **43** is shown. Air bearing side **43** of slider **41** comprises a patterned set of elements, such as air bearing surface (ABS) pads **45** and one irregularly-shaped pocket surface **47** recessed from ABS pads **45**. The size, shape, and pattern of ABS pads **45** are merely representative of those available. For reference purposes, a longitudinal direction is defined vertically from top to bottom, and a lateral direction is defined horizontally from side to side (left and right). Pocket **47** is manufactured using standard etching techniques such as reactive ion etching (RIE) and ion milling (IM), for example. Common etch depths range from about 0.1 to 5 microns. The top surface of the ABS pads **45** are also known as air bearing surfaces (ABS). In the embodiment shown, slider **41** has three protruding ABS pads **45** and one continuous but very irregular pocket **47** (approximately 1.50 microns recessed from ABS pads **45**) that extends to portions of the leading edge **49**, lateral edges **51**, **53**, and trailing edge **55**. Lateral edges **51**, **53** also represent the inner and outer radial directions, respectively, of disk **15**. The trailing edge **55** of slider **41** is located along the rear edge of pocket **47**.

In each of the four corners of air bearing side **43** there is formed a layer **57** of shock-absorbing and wear-resisting material that can be bonded or sputtered to pocket **47**. These protrusions **57** are easily manufactured since slider **41**, which is made in a wafer methodology, can be easily sputtered with rubbing or tribo-resistant material. Each of the sliders in the process batch can be masked off in the various critical regions and the sputter material can be attached in the appropriate locations, such as corners **57**. The material sputtered or glued to the slider **41** is ideally attached to pocket **47**. The polymer or metal protrusions **57** on the corners are suitably slightly higher than the ion-milled surface of pocket **47**, as long as it will not affect the flying height of slider **41**. In one version, the presence of the material on the corners raises

those protrusions 57 to within approximately 0.15 microns of the air bearing surface of pads 45. If flying height is affected, air bearing 43 may be redesigned to compensate for the material added to the slider.

5 The material sputtered on slider 41 can range from metals, such as Au, Cu, Ag, Pt, Sn, and Al, and copper oxide. Polymer materials that also can be used include Teflon®, Vectra®, and other materials from which the load/unload platform 39 (Figure 1) is made. In addition,

10 carbon and doped carbon in the form of nitrogenated or hydrogenated carbon are suitable.

15 The metal or polymer material that is deposited onto the slider can be selected on the basis of a good tribological match between the deposited material and the surface of the disk. Because disk surfaces range from aluminum to glass substrates with carbon overcoatings, including hard, soft, cold, and hot sputtered-type carbon, there are many different matching materials that provide excellent wear properties. For example, both copper and gold are excellent sputtered metals. When the slider surface is appropriately sputtered with a thin layer of copper or gold, excellent wear properties are obtained. Load/unload experiments showed that no soft or hard errors were generated in the loading zone which had been pre-patterned with magnetic digital data. Without the copper coating, a “bare” slider causes many hard errors and loss of magnetic digital data and, upon close examination, the surface of the disk shows scarring and scratching.

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 The tribo-coating serves as a tribological shock resistance layer at or below the ABS in situations where the slider comes into direct contact with the disk and cannot

establish a thin-film air bearing protection between the ABS pads and the disk. Because of rolling or pitching of the slider when under shock or loading from the load platform, portions of the slider come into direct contact with the disk surface. However, due to the excellent wear properties of the added materials, no deleterious wear effects are realized. The disk surface is protected from scarring, scratching, and dings. The magnetic data information is thereby protected from irreversible erasures. The coated portions of the slider are protected as well, but are allowed to have some “wear-in” phenomenon. Because of the critical choice of a soft material or excellent wear material deposited on the slider, the deposited material is preferentially worn away to allow the disk surface to remain pristine and without error. Thus, the slider becomes a wear protector that reduces erasures, and tracks or sectors from disappearing when the disk drive is bumped, dropped, or experiences many load/unload operations.

Referring now to **Figures 3 and 4**, alternate embodiments of the present invention are depicted as sliders **61** and **63**, respectively. Slider **61** of **Figure 3** is essentially identical to slider **41** of **Figure 2**, except that it has been coated along the lateral side edges **65, 67** of its etch pocket **69** instead of its corners. As described above for the previous embodiment, the pads **71** of the air bearing **73** are not coated. However, the pocket **75** on slider **63** of **Figure 4** is completely encased in the overcoating material. Again, only the ABS pads **77** are not coated. Pads **77** may be shielded from the coating by masking them off during the entire sputtering process. This version of the invention may be advantageous in certain manufacturing situations where corners or side edges are not preferred, and the entire surface of the slider may be protected by the addition of an overcoat.

The present invention has several advantages. The shock and wear protection of hard disk drive sliders is achieved by sputtering or layering alternate materials on

the corners, sides, edges, or entire surface of the slider, except for the ABS pad surfaces. this protection is a tribological wear enhancement of the sliders. With this new type of slider that is protected by alternate composite materials, disk defects and hard or soft errors can be minimized or totally eliminated. Disk dings and scratches, which usually occur when the slider unloads onto the surface of the disk, can be eliminated by affording a "soft contact protection" due to the excellent tribological wear material located on the slider. It is these portions of the slider that first come into contact with the disk when the slider does an unload operation from the ramp. During the unload operation, the air bearing is not given sufficient time to establish, and, due to the roll attitude of the slider oriented to the disk, the first feature that comes into contact with the disk is typically the edge or corner closest to the disk relative to the slider. When a material such as copper or gold is attached to the slider surface, the hard errors disappear entirely when compared to a control slider without any coating. With this type of slider, the load/unload zone which typically does not contain data, can now become a dedicated data real estate zone.

The present invention also aids disk drives in handling operational and non-operational shock. Currently, the shock resistance nature of disk drives is rather poor. Typical values for shock protection requires operating disk drives under 350 g's for non-operational shock, and 60 g's for operational shock. With sliders fabricated with the shock-protecting materials as disclosed above, these shock value tolerances can increase by two or three fold. This increase is due to the softer material being in contact with the disk surface, rather than a harder surface of the slider (typically, the alumina and titanium carbide composite used in sliders has a very high hardness). The soft material overcoat is somewhat elastic and more shock-forgiving than the base material of the slider. In a shock situation, such as dropping or bumping the disk drive, the sliders contact the disks when they are operating over a data region. The first part of the slider to contact the disk is an edge or corner. The material on the slider elastically bounces off the disk without inflicting any damage to the disk

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While the invention has been shown or described in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the invention.